

(19)



Europäisches Patentamt
European Patent Office
Office européen des brevets



(11) Publication number:

0 536 607 A2

(12)

EUROPEAN PATENT APPLICATION(21) Application number: **92116446.3**(51) Int. Cl.⁵: **C03C 17/36, C03C 17/34**(22) Date of filing: **25.09.92**

(30) Priority: **30.09.91 US 768791**
29.11.91 US 799806

(43) Date of publication of application:
14.04.93 Bulletin 93/15

(84) Designated Contracting States:
CH DE ES FR GB IT LI LU SE

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(54) **Heat processable metallic appearing coatings.**

(57) A heat processable metallic appearing coated article is prepared by coating a glass substrate with a metal-containing film such as chromium or titanium nitride, which ordinarily oxidizes at high temperature, and overcoating with a protective layer of a different metal which forms a dense oxide surface layer. The coated article is subjected to high temperature processing such as bending without losing its metallic appearance to oxidation. A temperable coated article with metallic properties is prepared by coating a glass substrate with a metal-containing film such as titanium nitride, which ordinarily oxidizes at high temperature, overcoating with a protective layer of a silicon compound which forms a durable layer and prevents oxidation of the underlying metal-containing film, and undercoating with a stabilizing metal-containing layer. The coated article can be tempered without losing its metallic properties to oxidation.

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BACKGROUND

This invention relates generally to the art of vacuum coating, and more particularly to the art of producing vacuum coatings which maintain a metallic appearance and other metallic throughout high temperature processes such as bending, laminating, and tempering.

Most vacuum coatings on glass which have a desirable metallic appearance and other metallic properties as deposited lose their characteristic metallic appearance and properties when subjected to high temperature processing. Vacuum coatings with a metallic appearance and other metallic properties, such as conductivity and infrared reflectance, are generally metals, metal nitrides, metal carbides or metal borides which oxidize when heated in air to form metal oxides which are electrically insulating, more transparent and less absorbing. While many metals can be heated in air to the forming temperature of glass (600 to 700 °C) developing a protective oxide surface layer, the thinness of transparent metallic coatings and their consequent non-bulk, even porous, nature prevent the formation of a suitable protective layer. Thus thin transparent metallic appearing films generally cannot be heated to temperatures at which glass can be bent without degradation of metallic properties.

U.S. Patent No. 4,992,087 to Holscher discloses a process for the production of a tempered or bent glass plate with a transmission-reducing coating in which to one side of the glass plate is applied at least one opaque metal coating predominantly at least one metal or alloy of elements 22 to 28, and a metal-containing protective coating of an alloy of aluminum and at least 10 atomic percent titanium and/or zirconium and thickness selected such that during tempering or bending there is no significant oxygen diffusion to the metal coating.

A titanium nitride coating has metallic properties that make it suitable for a durable solar control coating. By changing the coating thickness, the transmission and solar properties can be varied, and by adding the appropriate combination of dielectric layers, reflectance and color can be varied while maintaining chemical and mechanical durability.

Such coated articles have particular application in monolithic automotive glazing. When the coating is deposited on a dark substrate such as Solargray® glass it can be used for privacy glazing with enhanced solar properties and a desired reflectance and color. On clear glass the titanium nitride layer can be adjusted to allow for greater than 70 percent transmittance of Illuminant A (LTA) with low internal reflectance, neutral appearance and enhanced solar properties. However most vehicle transparencies are bent and tempered.

SUMMARY OF THE INVENTION

Vacuum coatings with a metallic appearance as deposited can be made to retain their metallic appearance upon bending by overcoating with a different metal which forms a dense oxide. Further improvement in oxidation resistance of the metallic film can be attained by introducing additional interfaces formed by another layer of a different material, particularly an amorphous metal oxide.

Vacuum coatings of metal compounds having metallic properties, such as titanium nitride, which retain their metallic properties when overcoated with a dielectric material, are stabilized for tempering by the addition of a malleable metal, alloy or semiconductor layers below the titanium nitride. Such an underlayer, which has a thermal expansion coefficient equal to or less than that of the substrate, has good adhesion to the glass substrate and titanium nitride layer, eliminates the problems of haze, mottle, picture framing and surface contamination, and greatly increases the operating temperature range for tempering. Preferred underlayer materials include silicon, titanium, zirconium, tantalum, chromium, niobium, silicon alloys and nickel-chromium alloys.

DESCRIPTION OF THE DRAWINGS

Figure 1 compares the reflectance of a heated but unoxidized metallic layer in accordance with the present invention (A) with the reflectance of an oxidized metal layer (B) and the reflectance of an unheated metallic layer (C).

Figure 2 compares the transmittance of a heated but unoxidized metallic layer in accordance with the present invention (A) with the transmittance of a heated oxidized metallic layer (B) and the transmittance of an unheated metallic layer (C).

Figure 3 illustrates a coated article of the present invention with substrate 10 coated with a first malleable metal-containing layer 20 which stabilizes a second metal compound layer 30 with metallic properties which in turn is protected from oxidation by a silicon-based dielectric layer 40.

Figure 4 illustrates the transmittance as a function of wavelength for a coating of the present invention before and after heating at 1300° F (704° C) for 3.5 minutes.

DESCRIPTION OF PREFERRED EMBODIMENTS

In accordance with the present invention, some of the more oxidation resistant coatings, preferably chromium nitride and titanium nitride, which nevertheless normally oxidize quite quickly at 700° C, can be protected from such oxidation by another oxidation resistant metal. The protective layer must be dense to prevent oxidation of the underlying metallic layer. Since metal oxides are generally not sufficiently dense as deposited in vacuum, the protective layer is deposited as a metal which forms a dense oxide surface layer which prevents oxidation of the underlying material. The metal of the protective layer must be different from the metal of the metallic layer in order to prevent oxidation from proceeding through the interface. Thus, for example, a titanium protective layer will prevent oxidation of a chromium nitride layer, whereas a chromium layer will not. Similarly, a titanium protective layer will not protect a titanium nitride layer from oxidation, whereas a silicon protective layer will.

An unprotected coating oxidizes upon heating, which results in higher transmittance and lower reflectance than a metallic coating protected in accordance with the present invention, as shown in Figures 1 and 2, as well as a hazy and translucent appearance. In contrast, a metallic appearing vacuum coating of e.g. chromium nitride or titanium nitride, protected by a different oxidation resistant layer such as titanium or silicon respectively, in accordance with the present invention, will retain its characteristic metallic reflectance, transmittance and absorbance properties upon heating to glass bending temperatures as shown in Figures 1 and 2. The slightly lower reflectance and higher transmittance of the heated coating are the result of oxidation of the surface of the protective layer.

Further improvement in oxidation resistance can be attained by introducing additional interfaces formed by yet another different type of material. This material is preferably glassy, e.g. an amorphous metal oxide, such as zinc-tin oxide, preferably of approximate composition Zn_2SnO_4 .

In order to use titanium nitride on a flat glass substrate which is subsequently tempered, it has now been discovered that it must not only be protected from oxidation by means of a protective overcoat layer, but also must be stabilized, for example, against glass-substrate-titanium nitride layer interaction or stress-induced "breakdown" which occur at the high temperatures required for tempering. For example, a coating of titanium nitride/silicon nitride made by a magnetron sputtering process, where the silicon nitride overcoat prevents oxidation of the titanium nitride, was found not to survive tempering for silicon nitride layer thicknesses up to 800 Angstroms. Such a coating becomes hazy, mottled, crazed and develops a picture frame effect (coating breakdown around the edge of glass plate) after tempering. In addition, the coating is susceptible to glass surface contamination, such as packer belt marks, washer contamination in the form of streaks, or spots in the coating after heating.

In accordance with the present invention, oxidation resistant metallic metal compound coatings, particularly titanium nitride, which nevertheless normally oxidize readily at 700° C, can be protected from such oxidation by dielectric oxides or nitrides if a stabilizing layer is deposited below the titanium nitride layer as well. These stabilizing layers should have good adhesion to the adjacent layers, be somewhat malleable and have thermal expansion coefficients less than or equal to glass. The preferred stabilizing layers are silicon and silicon alloys, titanium, zirconium, tantalum, chromium, niobium, nickel-chromium and nickel-chromium containing alloys. Aluminum nitride can also be used as a stabilizing layer, particularly to maintain high transmittance. Silicon-aluminum as a stabilizing layer results in higher total solar energy transmittance (TSET) values than silicon-nickel and aluminum nitride for the same value of luminous transmittance of Illuminant A (LTA).

The stabilizing layer isolates the glass substrate from and provides a uniform controlled surface for the metallic metal compound layer. During the thermal process it prevents, for example, the titanium nitride layer from reacting with the glass surface and provides a mechanical transitional layer between the glass substrate and the titanium nitride layer. The stabilizing layer reacts with the glass surface forming an oxide, thus increasing in transmission, and still maintains bonding to the metallic metal compound. The stabilizing layer should be thick enough to isolate the metallic metal compound layer from the glass, yet thin enough to oxidize and provide maximum transmission, since this layer does not significantly enhance solar properties. The thickness of the stabilizing layer is preferably in the range of 5 to 100 Angstroms. A preferred stabilizing layer is silicon, preferably in the thickness range of 20 to 50 Angstroms. Titanium is another preferred stabilizing layer, particularly in the thickness range of 15 to 40 Angstroms.

Silicon alloy dielectrics are preferred for overcoats in accordance with the present invention. The silicon alloy dielectric used for the overcoat is critical in preventing coating breakdown during heating. Silicon can

be alloyed or doped with many different elements. Each element adds some unique property to the silicon, either in the form of a target material for sputter deposition or in the form of a sputtered coating. In addition, target fabrication, either by casting or plasma spraying, is facilitated by alloying. In accordance with the present invention elements alloyed or doped with silicon include aluminum, nickel, chromium, iron, nickel-chromium alloys, boron, titanium and zirconium. The amount of other metal alloyed with silicon varies by metal and is limited only by the desired properties of the target and the coating. Typically up to 50 percent by weight of additional metal in silicon is usable, preferably 5 to 25 percent alloying metal and/or up to 2 percent dopant.

Sputtering a planar target of silicon-nickel, for example, is more stable, with a 40 percent higher sputtering rate than sputtering a planar target of silicon-aluminum in an oxygen-argon gas mixture, and the effect of 20 weight percent nickel on absorption and refractive index of an oxide coating is insignificant for the applications described here. Silicon-nickel, however, when sputtered as a nitride is absorbing, the degree depending on the amount of nickel, where silicon-aluminum nitride is not. When index variation or absorption are desirable, for example with a privacy type coating, the alloy content can be varied. This gives the added flexibility of an additional layer to vary optical properties and particularly to decrease transmission. Chromium and chromium-nickel alloys behave similarly to nickel, with added chemical durability, particularly for the nitride coating. Silicon-aluminum nitride, on the other hand, is not as chemically durable.

Generally, silicon alloy oxide, nitride and oxynitride coatings all provide durable overcoats which assist in preventing oxidation of the underlying metallic metal compound layer during a tempering process. Silicon-iron is most effective with an additional layer over the metallic metal compound. In addition, the process of heating during tempering further enhances the chemical and mechanical durability of these layers. A silicon-aluminum or silicon-nickel nitride, oxide or oxynitride overcoat, for example, is particularly effective. A silicon-iron nitride is most effective with an intermediate silicon-aluminum nitride, aluminum nitride, silicon or silicon alloy layer between the titanium nitride and silicon-iron nitride layers. Silicon alloy oxide protective overcoats are particularly effective in the range of 400 to 1100 Angstroms, preferably 500 to 1000 Angstroms, thick, while silicon alloy nitride protective overcoats are particularly effective in the range of 125 to 1000, preferably 200 to 800 Angstroms thick.

Generally, for solar control glazing in automobiles, coating stacks typically consist of titanium nitride sandwiched between dielectric layers to form an interference coating stack and provide a protective overcoat. In accordance with the present invention, a stabilizing metal layer is inserted between the glass substrate and a layer of a metal compound with metallic properties. A preferred metal compound is titanium nitride, typically at a thickness of 20 to 1000 Angstroms, preferably at a thickness of 30 to 500 Angstroms. The metal compound layer is protected from oxidation by an overcoat of a dielectric material, preferably a silicon-based dielectric material. The coating is then stable in a bending or tempering process. The combination of these layers and the thermal processing enhance the properties of the coating. The solar properties of this tempered or bent coated glass with the stabilizing metal layer, titanium nitride and silicon alloy dielectric material are always superior to the equivalent unheated coating with no stabilizing layer. Preferred silicon-based dielectric materials are the oxides, nitrides and oxynitrides of silicon and silicon alloys containing, e.g. aluminum, nickel and/or chromium.

The silicon alloy oxide overcoat layer has particular application in vision areas of vehicles where luminous transmittance (LTA) requirements are greater than 70 percent, and durable, neutral appearing, antireflecting, solar enhanced glazing is required. Higher luminous transmittance (LTA) requirements, for example the European requirement of 75%, can be met by reducing the layer thickness of titanium nitride, which can also be done to compensate for the lower transmittance when tinted glass substrates are coated in accordance with the present invention.

Combinations of oxide, nitride and oxynitride layers may also be used as overcoats, however, in areas that do not have LTA requirements of greater than 70 percent. Silicon nitride or combinations of oxide, nitride or oxynitride as overcoat layers offer durable coatings with increased flexibility in the choice of color and reflectance. These overcoats have particular application for privacy glazing with enhanced solar properties.

The preferred coated articles of the present invention have the general configuration

glass/M1/M3/silicon(M2)dielectric

where M1 is a semiconductor or metal alloy or combination thereof, M2 is an element combined with silicon in the silicon alloy target, and M3 is the metallic metal compound to be protected from oxidation and stabilized during high temperature processing such as tempering. An optional intermediate layer may be

deposited between the metal compound and the silicon-based dielectric material.

With reference to Figure 3, a glass substrate (10) is coated by sputtering, first, a stabilizing layer (20) whose function is to prevent coating breakdown during high temperature processing. This is followed by a metallic metal compound layer (30) with metallic properties whose function is primarily to reduce solar heat load, and secondarily to fulfill aesthetic requirements. This layer may be followed by an optional intermediate layer (not shown) the function of which is to enhance, if needed, the performance of the protective overcoat and, optionally, to give increased flexibility in coating aesthetics and transmittance. Following this layer is the dielectric protective overcoat layer (40) whose function is to prevent oxidation of the metallic compound layer during high temperature processing and to provide a durable overcoat.

The stabilizing layer is preferably selected from the group consisting of silicon, titanium, zirconium, tantalum, chromium, niobium, silicon alloys, nickel-chromium alloys and aluminum nitride. The metal compound layer (30) with metallic properties, the function of which is primarily to reduce solar heat load and secondarily to provide aesthetics requirements, is selected from the group consisting of metal borides, metal nitrides, metal carbides and metal oxynitrides. The optional intermediate layer is preferably selected from the group consisting of silicon, titanium, silicon metal alloys and oxides, nitrides and oxynitrides thereof. Finally, the dielectric protective overcoat layer (40), the function of which is to prevent coating breakdown during high temperature processing and to provide a durable overcoat, is selected from the group consisting of nitrides, oxides and oxynitrides of silicon and silicon-metal alloys.

Additionally, to provide flexibility in controlling color, reflectance and transmittance along with meeting solar property requirements, optional layers can be sputtered. For example, a silicon nitride layer can be inserted between the stabilizing layer (20) and the metallic metal compound layer (30). Other optional layer sequences are stacking the metallic metal compound layers alternatively with the group selected for the stabilizing layer and, adding a metal layer over the protective overcoat layer (40). Layers can also be repeated, for example, additional metallic metal compound layer followed by protective overcoat layer can be sputtered over the protective overcoat layer (40).

In preferred embodiments of the present invention, the coatings are produced on a large-scale magnetron sputtering device capable of coating glass up to 100 X 144 inches (2.54 X 3.66 meters). In the following examples, the coatings are deposited on a smaller scale, using planar magnetron cathodes having 5 X 17 inch (12.7 X 43.2 centimeter) metal targets of e.g. chromium or titanium, or a 3-inch (7.6 centimeter) diameter rotating cathode of silicon or silicon alloy. In each example, 6 millimeter thick glass substrates pass the targets on a conveyor roll at a speed of 120 inches (3.05 meters) per minute. Base pressure is in the 10^{-6} Torr range.

The coatings are made by first admitting the sputtering gas to a pressure of 4 millitorr and then setting the cathode to a constant power. In each example, except where noted otherwise, 6 millimeter thick glass substrates pass under the targets on a conveyor roll at a speed of 120 inches (3.05 meters) per minute unless otherwise specified. This procedure is repeated for each layer in the configuration.

The coatings are tested for thermal stability by hanging 2 X 12 inch (5.1 X 30.5 centimeter) strips of coated 6.0 mm clear glass on tongs and lifting them into a 48 X 30 X 12 inch (1.2 X 0.76 X 0.3 meter) vertical "loft" furnace heated to 705°C. The strips are heated for 3.5 minutes, except where noted otherwise, to simulate tempering. Air quenching in the tempering process does not cause any coating degradation. To determine compatibility with a production process, coated glass plates 12 inches (0.3 meter) square were edged, washed, screened with a black band frit and tempered on vertical and horizontal furnaces. The coating properties were checked for transmittance, reflectance, color, and the solar properties of total solar energy transmittance and total solar infrared transmittance (TSET and TSIR). Taber abrasion tests were performed and percent haze recorded.

The invention will be further understood from the descriptions of specific examples which follow.

EXAMPLE 1

A coating of chromium nitride about 380 Angstroms thick is made by sputtering a chromium metal target (2 passes) at 7.5 kilowatts, 587 volts in pure nitrogen gas at a pressure of 4 millitorr until the luminous transmission is 9%. The coated glass is then heated for 10 minutes at 570°C. The coating is oxidized by the heat, and its transmittance curve is similar to B in Figure 2.

EXAMPLE 2

For comparison with Example 1, a coating of chromium nitride about 380 Angstroms thick is made by sputtering a chromium metal target (2 passes) at 7.5 kilowatts, 586 volts in pure nitrogen gas until the

luminous transmission is 10%. Then a layer of titanium metal about 40 Angstroms thick is deposited by sputtering a titanium target (one pass) at 0.5 kilowatts, 346 volts, until the transmission of the sample decreases to 8.9%. The sample is heated for 10 minutes at 570 °C and the coating, although its transmittance increases slightly, still has a metallic appearance, and shows spectrophotometric curves similar to (A) in Figures 1 and 2. When heated for 10 minutes at 625 °C the coating oxidizes.

EXAMPLE 3

A film of chromium nitride about 380 Angstroms thick applied as in the above examples to 9.6% transmission is overcoated with a layer about 60 Angstroms thick of zinc/tin oxide of approximate composition Zn_2SnO_4 made by sputtering a zinc-tin alloy target of Zn-2Sn composition at 1.8 kilowatts, 346 volts in a mixture of 50% oxygen, 50% argon by volume. The transmittance is 10.2%. Finally a layer of titanium metal about 40 Angstroms thick is applied as in Example 2 until the transmittance is 8.7%. The coating remains metallic in appearance after heating for 10 minutes at 570 °C and 10 minutes at 625 °C.

EXAMPLE 4

For comparison with Example 3, a coating with the same chromium nitride and titanium layers as in Example 3, but having a layer of titanium oxide about 40 Angstroms thick between the other two layers, is made by sputtering a titanium target at 8 kilowatts, 532 volts, in a 50% argon-oxygen mixture at a pressure of 4 millitorr (2 passes). The transmittance rises from 9.5% to 10.4%. The coating is oxidized after heating for 10 minutes at 625 °C.

EXAMPLE 5

A coating with the same chromium nitride and titanium layers as in Example 3, but having a layer of titanium nitride about 40 Angstroms thick between the other two layers, is made by sputtering a titanium target (one pass) at 6 kilowatts, 598 volts, in an atmosphere of pure nitrogen at a pressure of 4 millitorr. The coating is completely oxidized after heating for 10 minutes at 625 °C.

EXAMPLE 6

A layer of titanium nitride about 450 Angstroms thick is deposited by sputtering a titanium metal target in pure nitrogen gas at a pressure of 4 millitorr. The voltage is 764 volts and the power 8 kilowatts. After 4 passes the transmittance is 23.5%. The color is bluish metallic. After heating in air for 10 minutes at 570 °C, the coating is completely oxidized.

EXAMPLE 7

For comparison with Example 6, a layer of titanium nitride about 500 Angstroms thick is deposited as in Example 6. The transmittance is 20.2%. A layer of silicon about 200 Angstroms thick is deposited by sputtering an Airco Coatings Technology C-Mag rotary cathode having silicon target material at 1 kilowatt, 583 volts (2 passes). The transmittance is 10.8%. After heating for 10 minutes at 625 °C, the coating is still bluish and metallic appearing.

EXAMPLE 8

A layer of titanium nitride about 470 Angstroms thick is applied as in Example 6. The transmittance is 22.8%. A layer of silicon nitride about 100 Angstroms thick is applied from a C-Mag cathode as in Example 7, by sputtering a silicon target at 3 kilowatts, 416 volts in pure nitrogen gas at 4 millitorr. The transmittance rises to 25% after a single pass. The appearance of the sample is unchanged after heating for 10 minutes at 625 °C.

EXAMPLE 9

A titanium layer is deposited by sputtering a planar titanium cathode in argon at 0.6 kilowatts, 332 volts, to a transmission of 62 percent (1 pass), followed by 9 passes using a planar titanium cathode in pure nitrogen at 4.0 kilowatts, 536 volts, to a transmission of 18.5 percent, followed by 5 passes using a rotating

cathode with silicon-5% aluminum in pure nitrogen at 2.8 kilowatts, 473 volts to a transmission of 23 percent. The coating thicknesses for each individual layer in Angstroms are 25 Angstroms titanium, 400 Angstroms titanium nitride and 270 Angstroms silicon-5% aluminum nitride. The properties on clear glass, before and after heating, are the following:

C.I.E. CHROMATICITY COORDINATES

(1931 2 degree observer)

	<u>Reflectance</u>	<u>Unheated</u>	<u>Heated</u>
	(Illuminant D65)		
Film Side	Y	13.59%	10.31%
	x	.357	.3264
	y	.3767	.3411
Glass Side	Y	29.25%	19.11%
	x	.3042	.2945
	y	.3366	.3234
	<u>Transmittance</u>		
	(Illuminant A)		
	Y	24.11%	34.7%
	x	.4479	.4387
	y	.4156	.4165
	TSET	17.9%	21.7%
	TSIR	10.7%	10.3%

The transmitted total solar infrared radiation (TSIR) shows that the titanium nitride does not degrade after heating, but instead is slightly enhanced. This is also evident in the wavelength region greater than 900 nm where TSIR is up to 1 percent lower than the unheated sample. The abrasion resistance after heating is well below the required 2 percent haze limit for glass. The before heat scratch resistance is more than sufficient to survive the complete manufacturing tempering process (cutting, edging, washing, screening, and tempering) with no scratching or coating degradation.

This coating applied to 4.0 millimeter Solargray® glass for privacy glazing in automotive sidelights and backlights reduces luminous transmittance to approximately 20 percent and total solar transmittance to 13 percent.

EXAMPLE 10

The first layer is deposited by sputtering a planar silicon-7.5% nickel cathode in argon at 0.4 kilowatts, 500 volts, to a transmission of 81.4 percent (1 pass), followed by 1 pass at 90 inches (2.3 meters) per minute using a planar titanium cathode in pure nitrogen at 6.0 kilowatts, 596 volts, to a transmission of 53.7 percent, followed by 12 passes using a planar cathode with silicon-7.5% nickel in a 50 percent argon-50 percent oxygen gas mixture at 3.0 kilowatts, 348 volts to a transmission of 63.2 percent. The coating thicknesses for each individual layer are 23 Angstroms of silicon-7.5% nickel, 100 Angstroms of titanium nitride and 790 Angstroms of silicon-7.5% nickel oxide.

The properties on 6.0 millimeter clear float glass before heating (Unheated) and after heating at 1300° F (704° C) for 3.5 minutes (Heated) as illustrated in Figure 4 are the following:

C.I.E. CHROMATICITY COORDINATES
(1931 2 degree observer)

<u>Reflectance</u>			
	(Illuminant D65)	<u>Unheated</u>	<u>Heated</u>
5 Film Side	Y	3.28	3.02
	x	.3350	.3068
	y	.3187	.3443
10 Glass Side	Y	13.25	9.51
	x	.3102	.3037
	y	.3388	.3323
<u>Transmittance</u>			
	(Illuminant A)		
20	Y	63.21	70.88
	x	.4511	.4431
	y	.4140	.4120
25	TSET	52.56	55.26
	TSIR	43.84	40.38

Figure 4 shows the percent transmittance as a function of wavelength (in nanometers) in the solar region of the spectrum both before and after heating. These data show that the transmittance increases in the visible but decreases in the infrared after heating thus enhancing the total solar performance of the coating.

When this coating is deposited on heat absorbing glass such as Sollex® glass, the titanium nitride layer is reduced to 45 Angstroms for 4.0 mm Sollex glass to meet the 70 percent (Illuminant A) transmittance requirement. The solar properties of this coating on 4.0 mm Sollex glass after heating for 1.75 minutes at 1300° F are TSET = 47.78 percent and TSIR = 27.67 percent for an Illuminant A transmittance of 71.03 percent.

The resulting coating is antireflecting from the film side and has neutral appearance in both transmittance and reflectance. The transmittance (Illuminant A) is maximum and TSET minimum for silicon-7.5% nickel oxide thicknesses in the range from 790 Angstroms (12 passes) to 925 Angstroms (14 passes) with titanium nitride thicknesses less than or equal to 100 Angstroms.

The silicon-7.5% nickel layer described in this example (0.4 kilowatt) is the minimum thickness for a stable coating after tempering. Coating breakdown, as described earlier, will occur rapidly for thinner layers. Onset of coating breakdown can be seen as the transmission drops as the primer layer is decreased. On the other hand, the coating will not meet the required light transmission of 70 percent or greater (Illuminant A) if the primer layer is sputtered at greater than 0.7 kilowatts (40 Angstroms). Generally, if this layer is sputtered at 0.6 kilowatts, 525 volts, resulting in 73 percent transmission on 6.0 millimeter clear glass after 1 pass (34 Angstroms), the coating will be stable with transmission above 70 percent (Illuminant A).

EXAMPLE 11

A coated article prepared as in Example 10, but having the configuration

glass/Si-5%Al/Ti nitride/Si-5%Al nitride

is stable with tempering with a Si-5% Al thickness greater than or equal to 25 Angstroms for a Si-5% Al nitride layer greater than or equal to 125 Angstroms.

EXAMPLE 12

A coated article prepared as in Example 11, but having the configuration

5 glass/Si-8%Fe-.25%B/Ti nitride/Al nitride/Si-8%Fe-.25%B nitride

is stable with tempering with a Si-8%Fe-.25%B thickness of 25 Angstroms, aluminum nitride thickness of 80 Angstroms, and a Si-8%Fe-.25%B nitride thickness of 200 Angstroms. Although aluminum nitride dissolves in water, for a coating with the above configuration, the unheated coating survives boiling in water for 30 minutes and is stable with tempering. The heated coating also survives boiling for 30 minutes. Si-8%Fe-.25%B is used when absorption is desirable in the coating, for example in privacy glazing.

EXAMPLE 13

15 A coated article is prepared as in the previous examples, having the configuration

glass/Si-8%Fe-.25%B/Ti nitride/Si-8%Fe-.25%B/Si-8%Fe-.25%B nitride.

The coating is stable with tempering for Si-8%Fe-.25%B thicknesses of 25 Angstroms and Si-8%Fe-.25%B nitride thickness of 350 Angstroms. The additional layer gives increased flexibility in varying color, transmittance and reflectance in addition to thermal stability.

EXAMPLE 14

25 Coatings are prepared as in the previous examples, having the configuration

glass/Ti/Ti nitride/Si-13%Al nitride or oxynitride:

These coatings illustrate the differences between the Si-M2 nitride and oxynitride overcoats. Both of these coatings are stable with tempering. The first three layers of both coatings are made by sputtering on 6 millimeter clear glass the layers as described in Example 1, except the 9 passes of the titanium nitride layer were sputtered at 4.4 kilowatts, 543 volts to a transmission of 16.5 percent. The thickness of the titanium nitride layer was 440 Angstroms. Both overcoat layers were then sputtered to the same physical thicknesses of 220 Angstroms. The Si-13%Al nitride overcoat layer was made by sputtering 5 passes from a planar cathode in pure nitrogen at 3.0 kilowatts, 456 volts to a final transmission of 19.7 percent. The Si-13%Al oxynitride layer was made by sputtering 5 passes from the same planar cathode in a 6 percent oxygen - nitrogen mix at 2.6 kilowatts, 450 volts to a final transmission of 18.9 percent. The CIE color coordinates were then compared for the coating after heating on both the film and glass sides.

	Reflectance	Nitride	Oxynitride
30 Film Side	Y(D65)	12.08%	15.42%
	x	.3292	.3341
	y	.3311	.3288
45 Glass Side	Y(D65)	20.2%	17.94%
	x	.2973	.2977
	y	.3219	.3114

50 From the above results it can be seen that as the overcoat with constant physical thickness goes from nitride to oxynitride there is a color shift and change in reflectance due to change in the coating index.

EXAMPLE 15

55 A coated article prepared as in the previous examples having the configuration

glass/Si-7.5%Ni/Ti nitride/Si-10%Cr nitride

is stable after tempering, for example, with the Si-10%Cr nitride layer in the thickness range 290 Angstroms to 1050 Angstroms for titanium nitride layer thickness of 100 Angstroms and Si-7.5%Ni layer thickness of 34 Angstroms.

The first two layers of this coating are made by sputtering on 6.0 millimeter clear glass as described in Example 4. The third layer is made by sputtering 4 passes from a planar Si-10%Cr cathode in pure nitrogen at 3.0 kilowatts, 510 volts to a final transmission of 53.1 percent. The thickness of this layer is 290 Angstroms.

The above examples are offered only to illustrate the present invention. Other metal, metal nitride and metal carbide metallic appearing films may be protected from oxidation by dense oxide surface forming metal layers as described above. Other metal nitride, metal carbide and metal boride metallic films and composition ranges may be used as the metallic metal compound layer with other oxide, oxynitride and nitride layers used as the protective overcoat, and other stabilizing metal layers. Deposition conditions will vary according to equipment and material being deposited. Coating thicknesses can be varied to produce the desired reflectance and transmittance properties. The scope of the present invention is defined by the following claims.

Claims

1. A heat processable, metallic appearing coated article comprising:
 - a. a transparent glass substrate;
 - b. a metallic appearing metal-containing film; and
 - c. a protective layer comprising a different metal from the metal-containing film which minimizes oxidation of the metal-containing film upon heating.
2. A coated article according to claim 1, wherein the metal-containing film is selected from the group consisting of metals, metal nitrides and metal carbides.
3. A coated article according to claim 2, wherein the metal-containing film is selected from the group consisting of chromium nitride and titanium nitride.
4. A coated article according to claim 1, wherein said protective layer is a metal which forms a dense oxide surface.
5. A coated article according to claim 4, wherein said protective layer is selected from the group consisting of chromium, titanium and silicon.
6. A coated article according to claim 1, wherein the metal-containing layer is chromium nitride and the protective layer is titanium.
7. A coated article according to claim 1, wherein the metal-containing layer is titanium nitride and the protective layer is silicon.
8. A coated article according to claim 1, wherein an amorphous metal oxide layer is deposited between the metal-containing layer and the protective layer.
9. A coated article according to claim 8, wherein said metal oxide layer comprises zinc and tin.
10. A coated article according to claim 9, wherein the metal-containing layer is selected from the group consisting of chromium nitride and titanium nitride, the protective layer is selected from the group consisting of titanium and silicon, and the amorphous metal oxide layer has the approximate composition Zn_2SnO_4 .
11. A temperable, metallic coated article comprising:
 - a. a transparent glass substrate;
 - b. a stabilizing layer selected from the group consisting of silicon, titanium, zirconium, tantalum, chromium, niobium, silicon alloys, nickel-chromium alloys and aluminum nitride;
 - c. a metal compound film with metallic properties; and
 - d. a protective layer which prevents oxidation of the metal compound film upon heating.

12. A coated article according to claim 11, wherein the metal compound film is selected from the group consisting of metal borides, metal nitrides, metal carbides and metal oxynitrides.
13. A coated article according to claim 12, wherein the metal compound film is selected from the group consisting of chromium nitride, titanium nitride, titanium boride, titanium carbide, zirconium nitride, hafnium nitride, tantalum nitride, niobium nitride, titanium oxynitride, zirconium oxynitride, chromium oxynitride, tantalum oxynitride, and niobium oxynitride.
14. A coated article according to claim 11, wherein said protective layer is selected from the group consisting of nitrides, oxides and oxynitrides of silicon and silicon-metal alloys.
15. A coated article according to claim 14, wherein said protective layer is selected from the group consisting of silicon oxide, silicon nitride, silicon oxynitride, silicon-nickel oxide, silicon-nickel nitride, silicon-nickel oxynitride, silicon-aluminum oxide, silicon-aluminum nitride, silicon aluminum oxynitride, silicon-iron oxide, silicon-iron nitride, silicon-iron oxynitride, silicon-chromium nitride, silicon-chromium oxynitride, silicon-nickel-chromium oxide, silicon-nickel-chromium nitride, silicon-nickel-chromium oxynitride, silicon-boron oxide, silicon boron nitride and silicon boron oxynitride.
16. A coated article according to claim 11, wherein the stabilizing layer contains a metal selected from the group consisting of silicon or titanium, the metal compound layer comprises titanium nitride, and the protective layer comprises silicon nitride, oxide or oxynitride.
17. A coated article according to claim 11, wherein the stabilizing layer is a silicon-metal alloy or titanium, the metal compound layer is titanium nitride and the protective layer is selected from the group consisting of silicon-metal alloy nitride, oxide, and silicon-metal alloy oxynitride.
18. A coated article according to claim 11, wherein an additional layer is deposited between the metal-containing layer and the protective layer.
19. A coated article according to claim 18, wherein said additional layer is selected from the group consisting of silicon, titanium, silicon-metal alloys and oxides, nitrides and oxynitrides thereof.
20. A coated article according to claim 19, wherein the stabilizing layer comprises silicon or titanium, the metal-containing layer is titanium nitride, the additional layer is selected from the group consisting of silicon, titanium, silicon-metal alloy and aluminum nitride, and the protective layer is selected from the group consisting of silicon oxide, silicon nitride, silicon oxynitride, silicon-nickel oxide, silicon-nickel nitride, silicon-nickel oxynitride, silicon-aluminum oxide, silicon-aluminum nitride, silicon aluminum oxynitride, silicon-iron oxide, silicon-iron nitride, silicon-iron oxynitride, silicon-chromium nitride, silicon-chromium oxynitride, silicon-nickel-chromium oxide, silicon-nickel-chromium nitride, silicon-nickel-chromium oxynitride, silicon-boron oxide, silicon boron nitride and silicon boron oxynitride.
21. A method of making a heat processed metallic appearing coated article comprising the steps of:
 - a. depositing on a surface of a glass substrate a metallic appearing metal-containing film;
 - b. depositing a protective layer comprising a different metal from the metal-containing film which prevents oxidation of the metal-containing film upon heating; and
 - c. heating the glass substrate on which are deposited said metal-containing film and protective layer to a temperature sufficient to bend the glass.
22. A method according to claim 21, further comprising the step of depositing an amorphous metal oxide between said metal-containing film and said protective layer.
23. A method of making a tempered metallic appearing coated article comprising the steps of:
 - a. depositing on a surface of a glass substrate a stabilizing film selected from the group consisting of silicon, titanium, zirconium, tantalum, chromium, niobium, silicon alloys, nickel-chromium alloys and aluminum nitride;
 - b. depositing a metal compound film with metallic properties on the stabilizing film;
 - c. depositing a protective layer comprising a silicon or silicon alloy dielectric which prevents oxidation of the underlying metal compound film upon heating; and

d. heating the glass substrate on which said films and layer are deposited to a temperature sufficient to temper the glass.

24. A method according to claim 22, further comprising the step of depositing an additional layer between
5 said metal compound film and said protective layer.

25. A method according to claim 24, wherein said additional layer is selected from the group consisting of
silicon, titanium, a silicon-metal alloy, nitrides, oxides and oxynitrides thereof.

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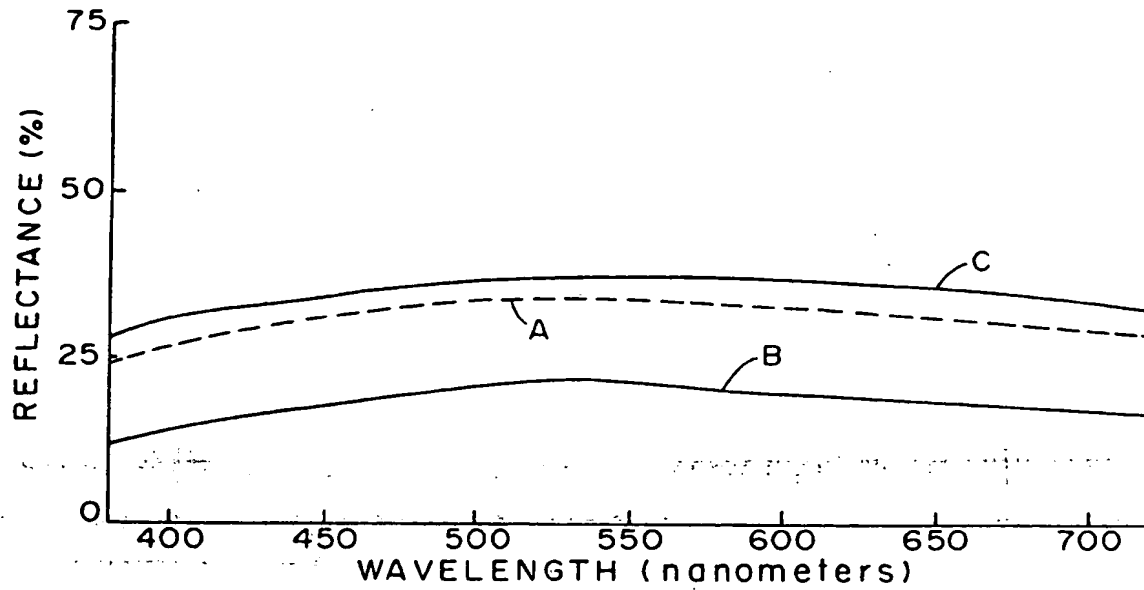


FIG. 1

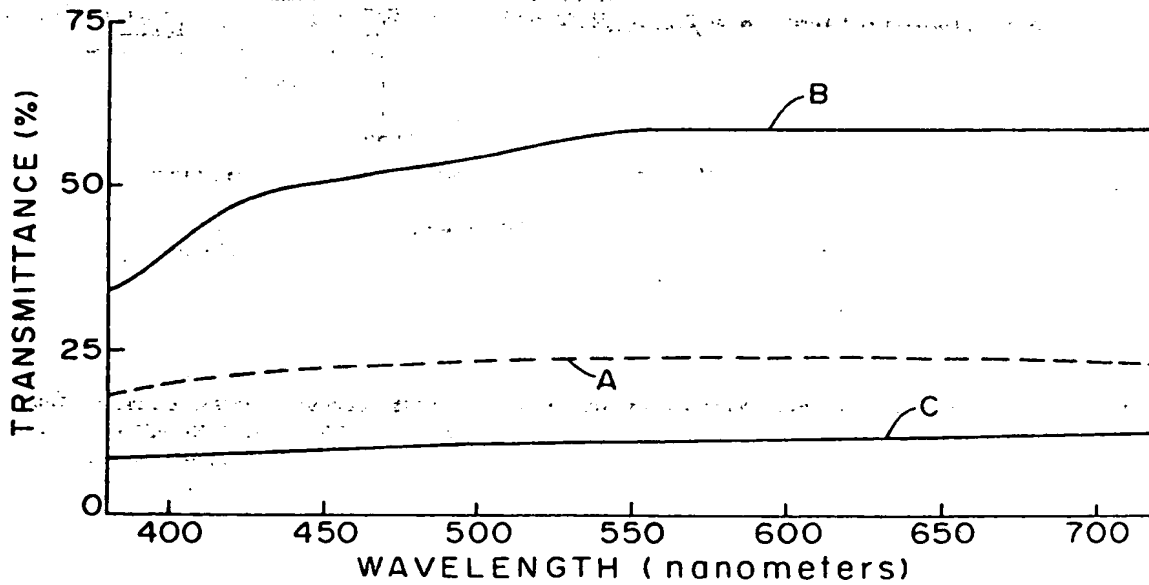


FIG. 2

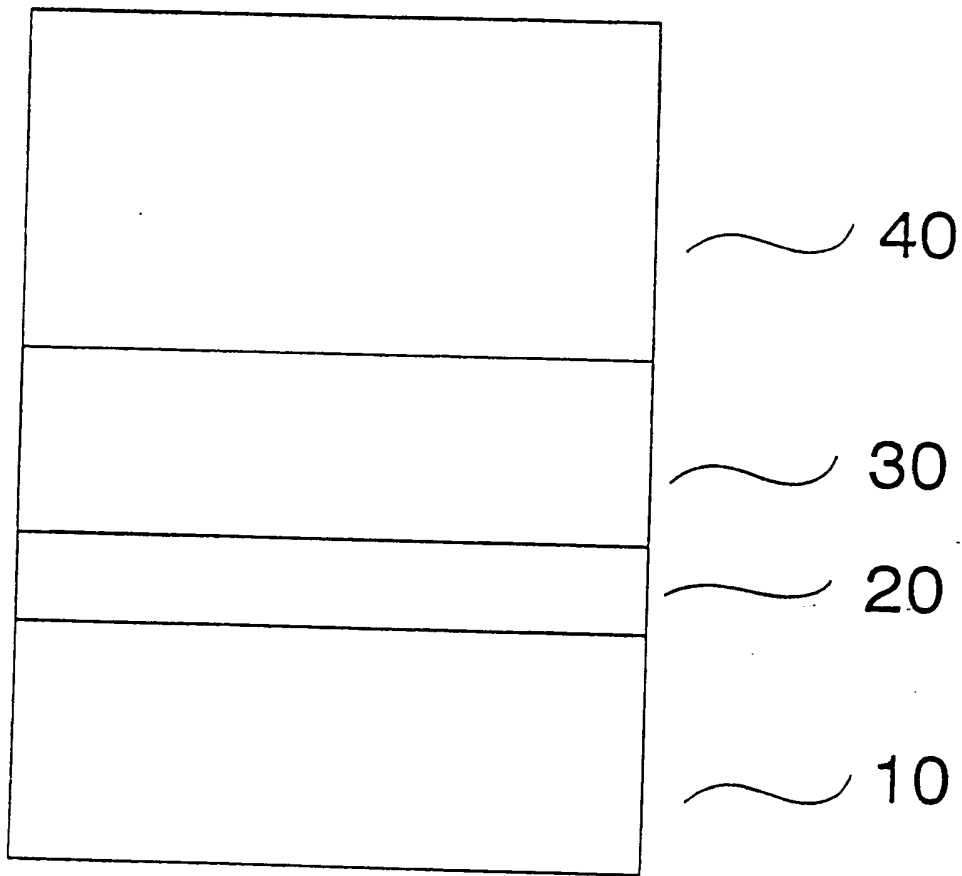


FIG. 3

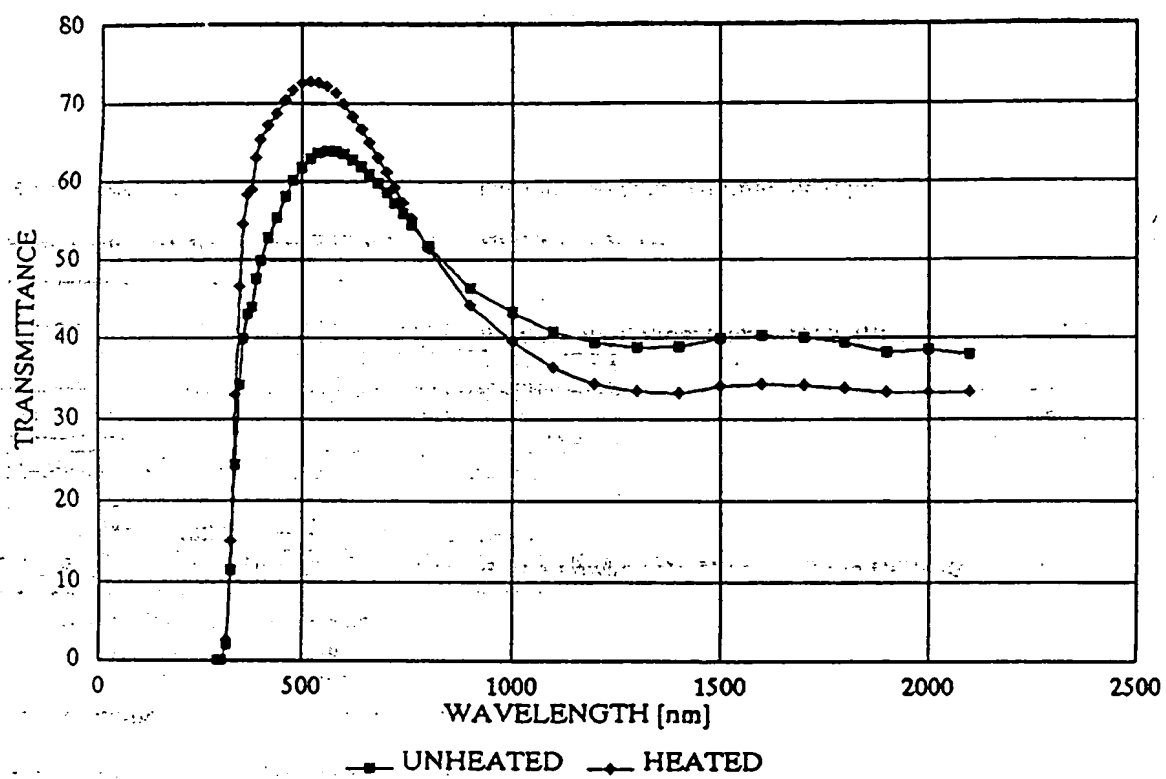


FIG. 4

(19)



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European Patent Office
Office européen des brevets



(11) Publication number:

0 536 607 A3

(12)

EUROPEAN PATENT APPLICATION(21) Application number: **92116446.3**(51) Int. Cl.⁵: **C03C 17/36, C03C 17/34**(22) Date of filing: **25.09.92**

(30) Priority: **30.09.91 US 768791**
29.11.91 US 799806

(43) Date of publication of application:
14.04.93 Bulletin 93/15

(84) Designated Contracting States:
CH DE ES FR GB IT LI LU SE

(66) Date of deferred publication of the search report:
30.06.93 Bulletin 93/26

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(54) **Heat processable metallic appearing coatings.**

(57) A heat processable metallic appearing coated article is prepared by coating a glass substrate with a metal-containing film such as chromium or titanium nitride, which ordinarily oxidizes at high temperature, and overcoating with a protective layer of a different metal which forms a dense oxide surface layer. The coated article is subjected to high temperature processing such as bending without losing its metallic appearance to oxidation. A temperable coated article with metallic properties is prepared by coating a glass substrate with a metal-containing film such as titanium nitride, which ordinarily oxidizes at high temperature, overcoating with a protective layer of a silicon compound which forms a durable layer and prevents oxidation of the underlying metal-containing film, and undercoating with a stabilizing metal-containing layer. The coated article can be tempered without losing its metallic properties to oxidation.



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EUROPEAN SEARCH REPORT

Application Number

EP 92 11 6446

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X Y	EP-A-0 301 755 (PIKLINGTON PLC) * claims 1,4-6 *	1-4,21 6,8-10, 22	C03C17/36 C03C17/34
X Y	EP-A-0 239 280 (R.G. GORDON) * page 2, column 2, line 34 - line 42 * * page 4, column 6, line 1 - line 5; claim 1 *	1-5,7,21 8-10,22	
X Y	EP-A-0 281 894 (FLACHGLASS AG) * claims 1,4 *	1,2,4,5, 21 6,8-10, 22	
Y	EP-A-0 226 993 (PPG INDUSTRIES) * page 3, column 4, line 1 - line 52 * * page 4, column 6, line 5 - line 31 *	8-10,22	
X	CHEMICAL ABSTRACTS, vol. 111, no. 2, 10 July 1989, Columbus, Ohio, US; abstract no. 11542q, page 271 ; * abstract * & JP-A-63 242 948 (ASAHI GLASS COMPANY LTD.) 7 October 1988	11-17,23	TECHNICAL FIELDS SEARCHED (Int. Cl.5) C03C
Y	BE-A-550 365 (DEUTSCHE TAFELGLAS AG DETAG) * claims *	11-17,23	
-/--			
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 12 MARCH 1993	Examiner REEDIJK A.M.E.
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons * : member of the same patent family, corresponding document	

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CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

- ☐ All claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for all claims.
- ☐ Only part of the claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid.
- namely claims:
- ☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirement of unity of invention and relates to several inventions or groups of inventions.

namely:

See sheet -B-

- ☒ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.
- ☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid.
- namely claims:
- ☐ None of the further search fees has been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims.

namely claims:



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EUROPEAN SEARCH REPORT

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Page 2

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5.)
Y	CHEMICAL ABSTRACTS, vol. 114, no. 18, 6 May 1991, Columbus, Ohio, US; abstract no. 169829k, page 346 ; * abstract * & JP-A-02 233 534 (CENTRAL GLASS CO. LTD.) 17 October 1990 -----	11-17,23	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 12 MARCH 1993	Examiner REEDIJK A.M.E.
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application I : document cited for other reasons * : member of the same patent family, corresponding document			

EPO FORM 1503 OL82 (P0401)



LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirement of unity of invention and relates to several inventions or groups of inventions, namely:

NON-UNITY IS STATED FOR THE FOLLOWING REASON:

1. Claims 1-10, 21, 22 : Deal with a metallic appearing metal containing film (see also claim 2)
2. Claims 11-20, 23-25 : Deal with a metal compound film with metallic properties (see also claim 13)

Even for the case that the metallic appearing coatings from the two sets of claims are identical, one must conclude, based on rule 30 of the European Patent Convention, that for this application there is non-unity.

For a problem that is known (oxidation of a metallic appearing coating during heat treatment: see search report), the two sets of claims give two different solutions

- 1: 2nd layer: protective layer (metal (Cr, Ti, Si) which forms dense oxide surface
1st layer: metal containing film
substrate
- 2: 3rd layer: protective layer (see claim 15), with composition different from 1st set of claims
2nd layer: metal compound (see claim 13)
1st layer: stabilizing layer: nitrides, oxides, oxy-nitrides of silicon and silicon-metal-alloys
substrate

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